Load-Balancing Introduction (with examples...)

For AFNOG 2014

By Laban Mwangi
Lmwangi _ ta _ gmail.com

(Rework of slides from Joel Jaeggli)

What is Load-balancing

- The act of dividing a workload between N > 1 devices capable for performing a task.
- Multiple contexts in internet services where this concept occurs.
  - DNS
  - MX records
  - Multiple links (L2 trunks, L3 ECMP)
  - Multiple servers

Goals

- Greater scalability
  - Horizontal scaling. Just add more switches/servers...
- Higher availability
  - Don't care about single device failure. Route around failures automatically!
- Reduced cost
  - Cheaper to use commodity hardware and architecture for failure. Examples: AWS/GCE...

amaze..

Quick Survey

- L2
  - LACP (Switches)
- L3
  - L3 ECMP (Switches, Routers, OS kernel)
- L4
  - HAProxy (OS userland)
- L4+
  - NGINX (OS userland)
  - HAProxy (OS userland)
  - F5, A10, Netscalar... (Hardware..)

Examples: L2 – Link aggregation

- Widespread support for LACP (Link Aggregation Control Protocol)
- Bond two physical layer 2 channels into one logical one.
  - Resilience against single port/channel failure.
  - L2 Bandwidth scaling
- Balancing and dynamic behaviour is important!

Examples: L3 - Equal-cost multi-path routing (ECMP)

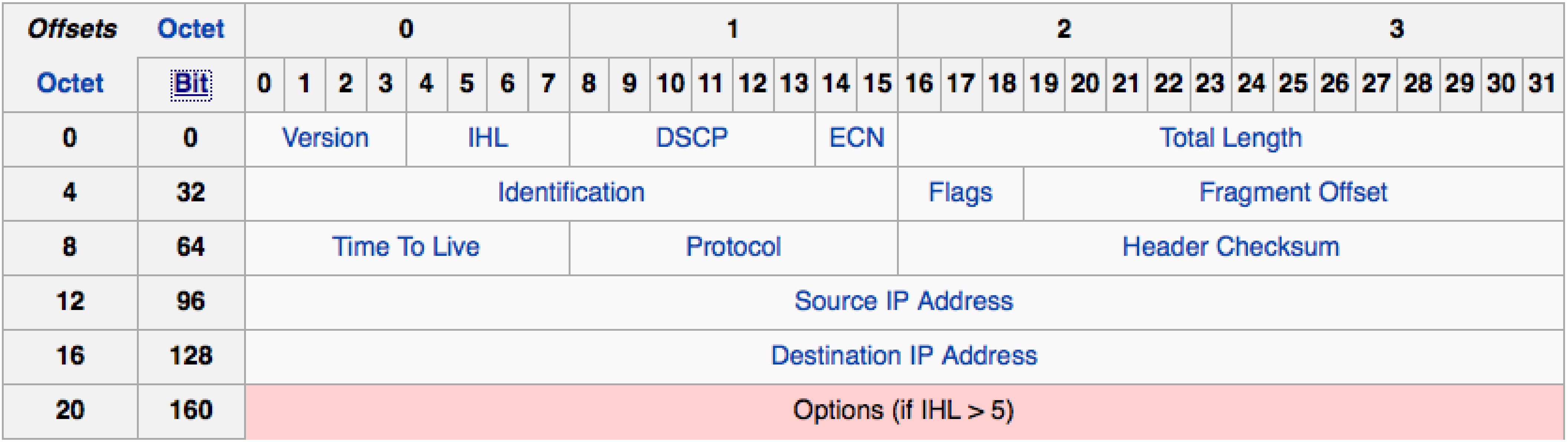
- Packets are forwarded to the next hop over links having an equal routing cost.
- Stateless mode breaks TCP (PMTU)
  - Different hops may have different MTU settings
  - TCP sensitive to re-ordering
- We need a way to make flows stateful.....

Examples: L4 - Equal-cost multi-path routing (ECMP) + hashing

- If packets in a TCP session take the same path...
  - Path MTU issues would be fixed
  - Re-ordering would be fixed
- Different TCP sessions can take different paths.
- We need a way to uniquely identify L4 sessions ....
- What attributes do you think would identify a TCP session?

Flow identification (5-tuple)

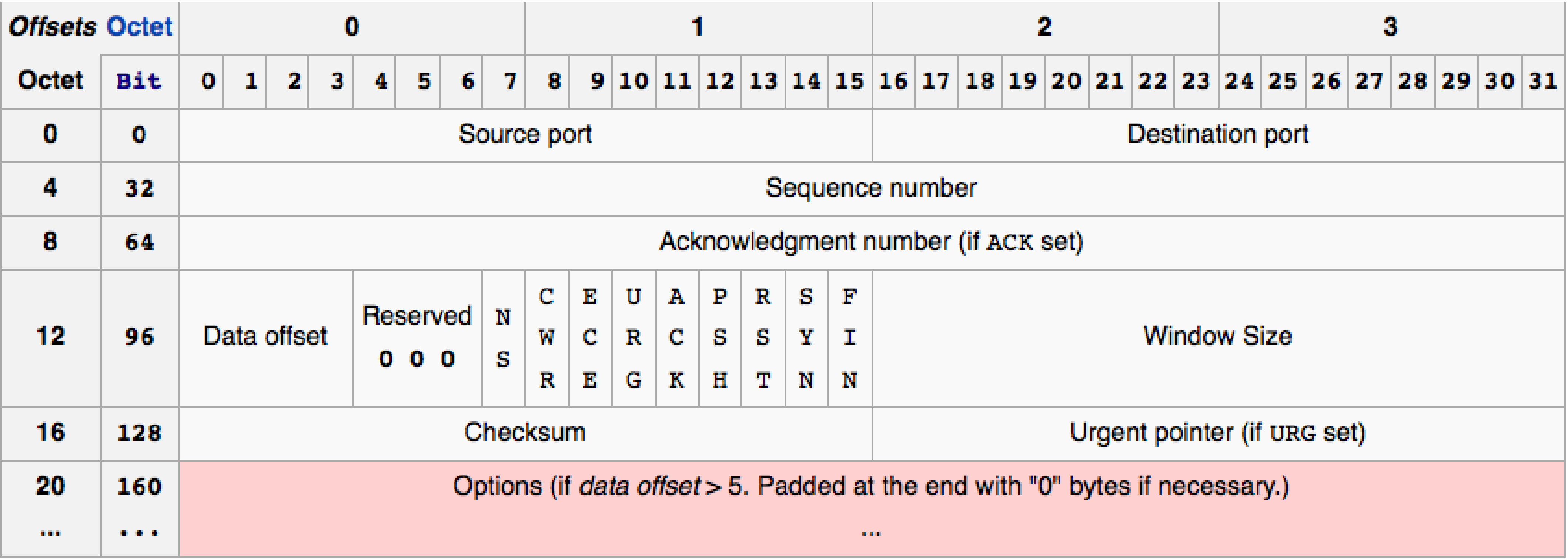
- XOR hash of fields to generate a flow id.
- Hash src & dest ip addresses, protocol number from the IP header and ....



Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version				IHL				DSCP						ECN		Total Length															
4	32	Identification																Flags			Fragment Offset												
8	64	Time To Live								Protocol								Header Checksum															
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160	Options (if IHL > 5)																															

5-tuple continued

- … hash of port numbers.
- How?
  - Example: CRC32(src_ip, dst_ip, pr_no, src_port, dst_port) % count of links



Offsets Octet		0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Source port																Destination port															
4	32	Sequence number																															
8	64	Acknowledgment number (if ACK set)																															
12	96	Data offset				Reserved 0 0 0			NS	CWR	ECE	URG	ACK	PSH	RST	SYN	FIN	Window Size															
16	128	Checksum																Urgent pointer (if URG set)															
20 ...	160 ...	Options (if *data offset* > 5. Padded at the end with "0" bytes if necessary.) ...																															

What does an L4 load Balancer do?

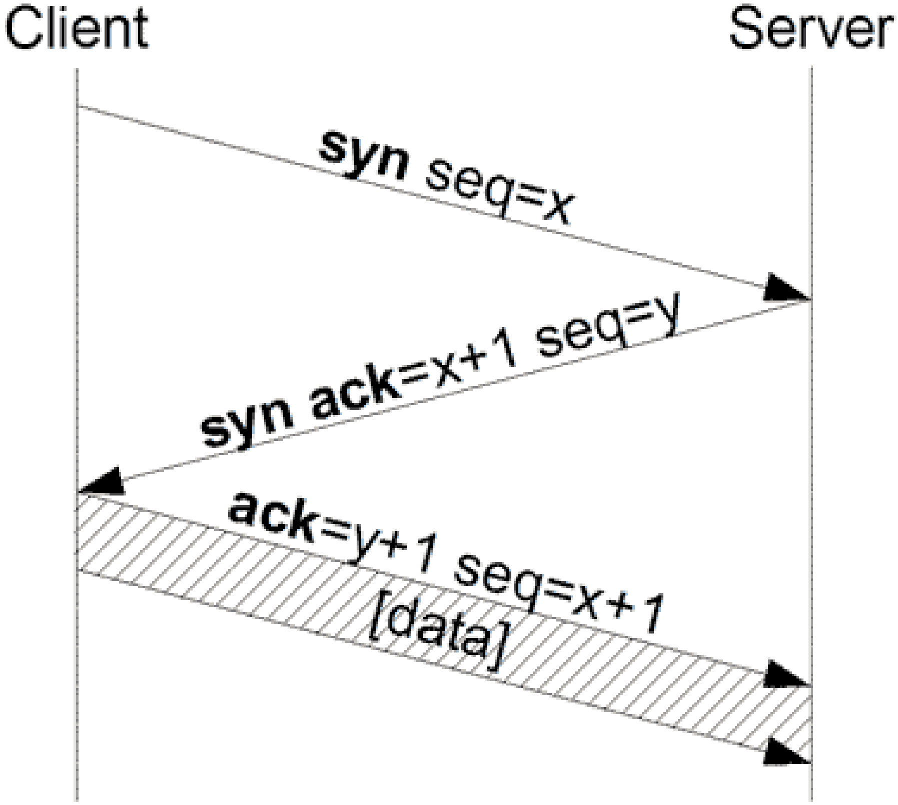
- Looks and the Destination IP and Port to determine which endpoint to send a packet/flow to in a pool of servers.
- Forwards the incoming connection to one pool member on the basis of policy (liveness, load).
- May keep the connection pinned to the particular pool member by tracking the connection.
- But... This breaks scaling!
  - Existing flows won't be remapped dynamically!
  - An LB/server failure would break a session!

What does an L7 load balancer do?

- An L7 load balancer answers incoming connection requests.
- It understands the protocol being spoken across the connection (e.g. HTTP IMAP FTP etc).
- On the basis of either 5-tuple hash or some higher layer value, (example a URI or a cookie or both) the request is directed to a member of the appropriate pool.
- L7 is another word for proxy or ALG (Application Layer Gateway).

Isn't L7 going to be slower than L4?

- Probably but not always.
- Importantly there are optimizations that can reduce the expense.
  - TCP syn-cookies
  - Connection pooling
  - Consider 3-way handshake



Applications - Cont

- Open source
  - Apache mod_proxy_balance
  - Squid
  - Haproxy
  - NGNIX
  - LVS

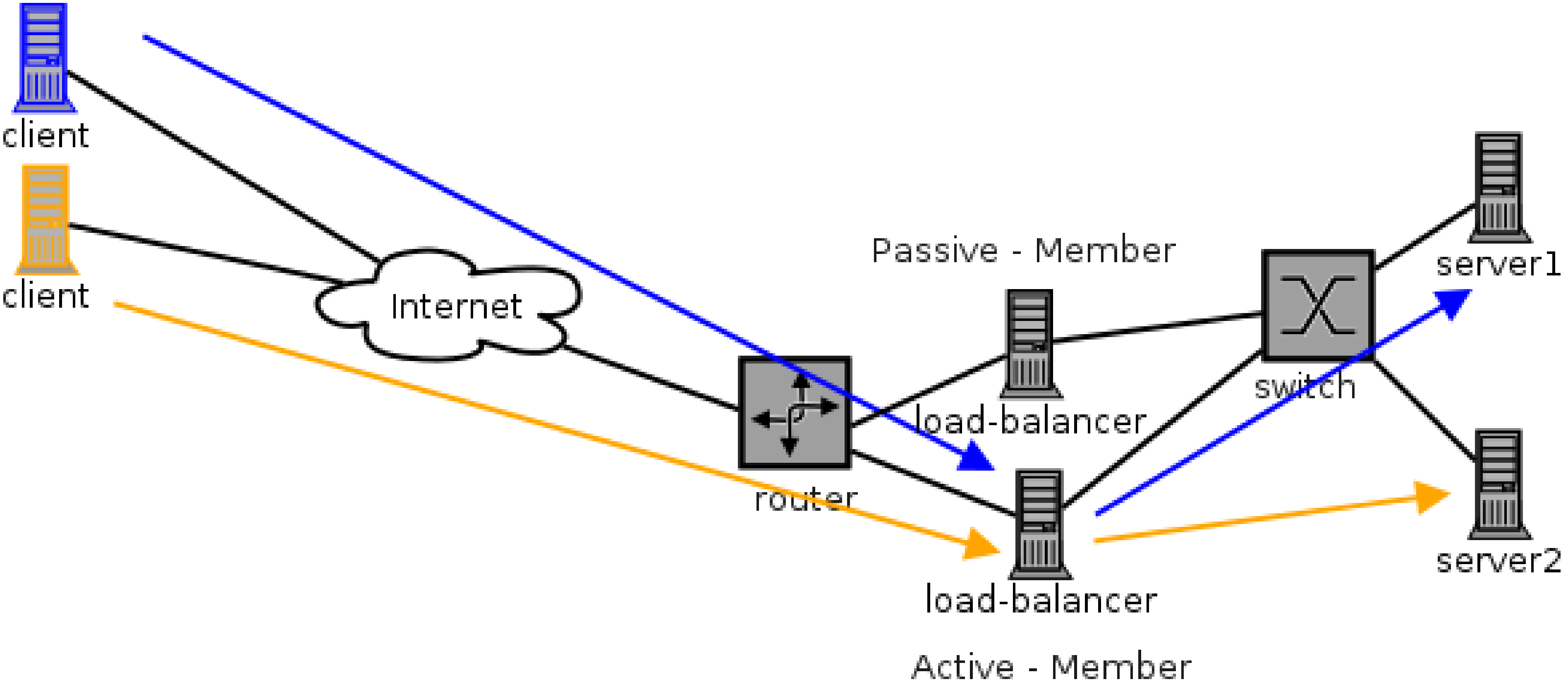
Applications Commercial

- Commercial
  - F5
  - Netscalar
  - A10
- Benefits of a commercial approach
  - Coordination of supporting elements
    - Routing
    - DNS
    - Complex health checks
    - HA
  - Can have ASIC based acceleration.

High Availability Approaches

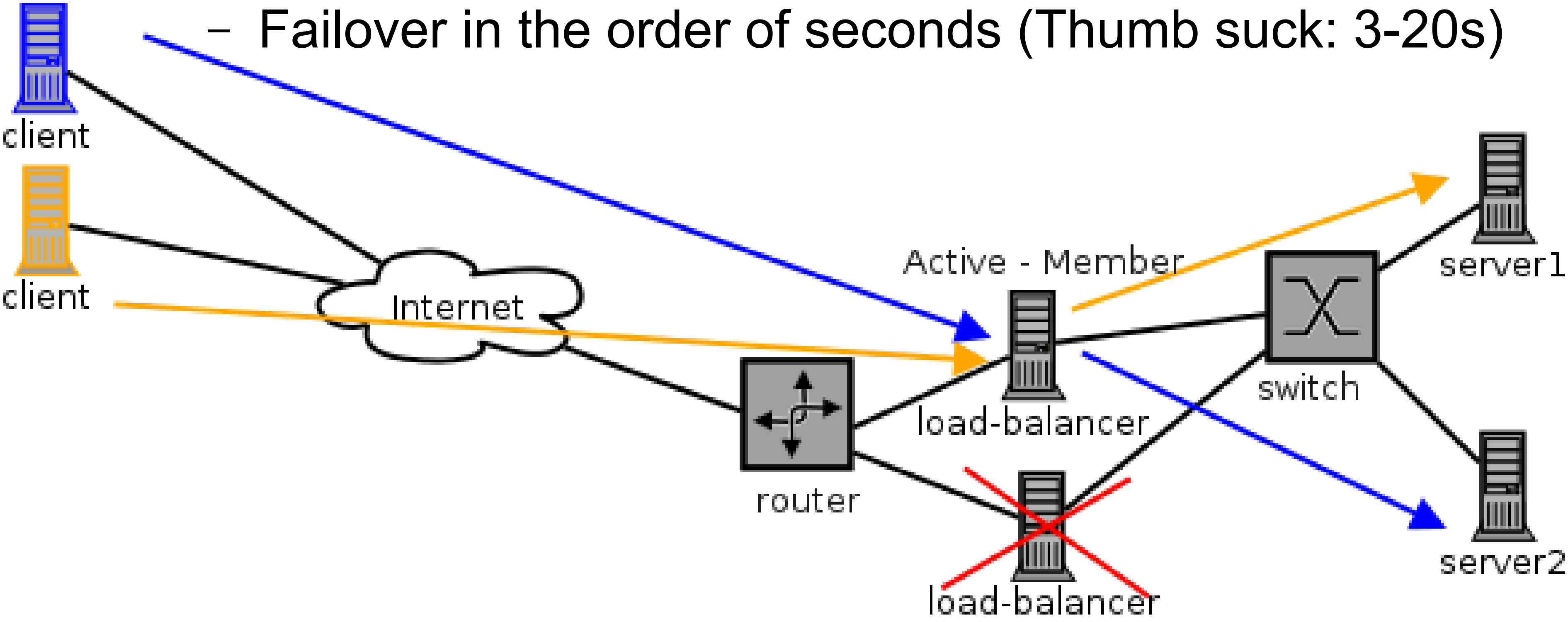
- Active-Passive
    - VRRP
    - State replication
- Active-Active
    - State-replication considerations
- Horizontally scaled
    - GTM – DNS based approach
    - L3ECMP (routed)

HA – active/passive



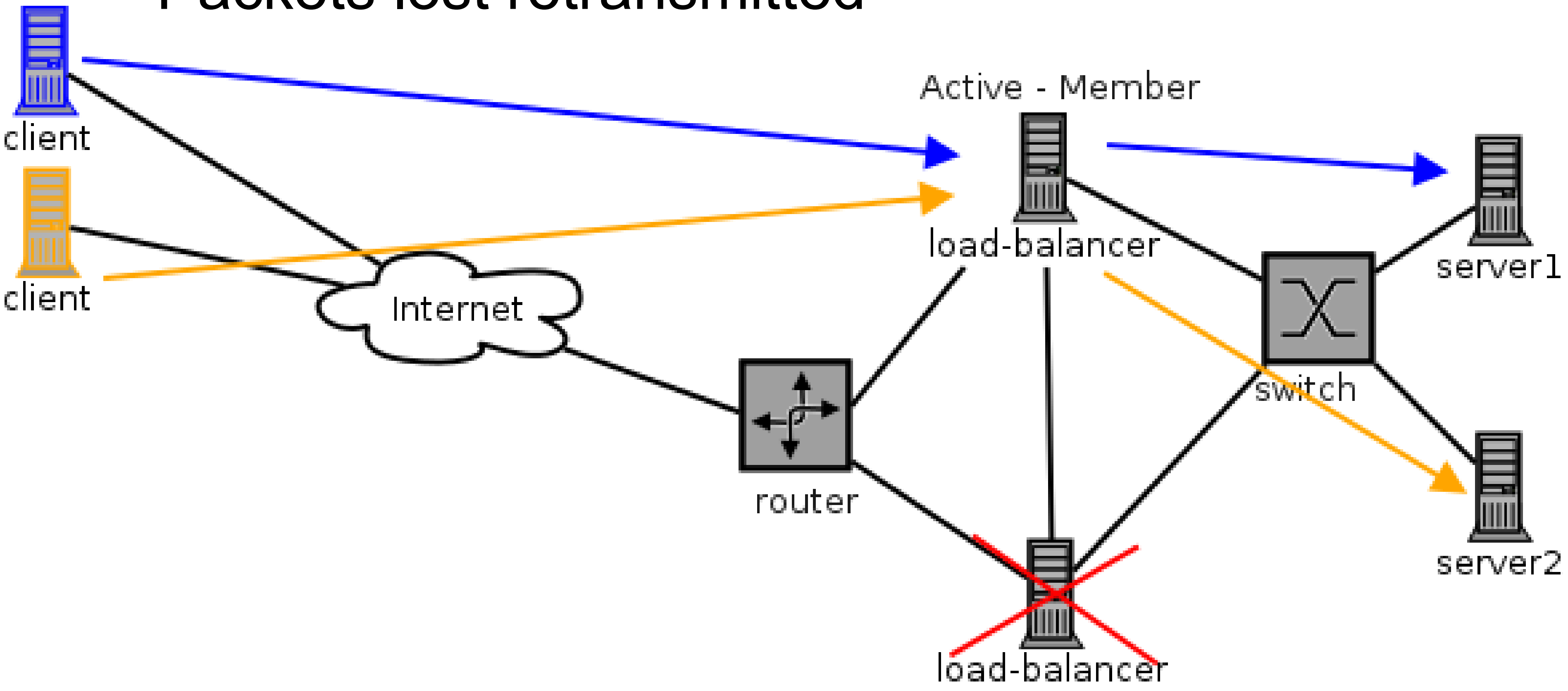
HA – active/passive - failover

- Connections terminated:
  - Stateless secondary
    - Secondary won't know which server to send packets to
    - TCP sessions will timeout and a new session initiated
    - Failover in the order of seconds (Thumb suck: 3-20s)



HA – active/passive failover with replication

- Connections work:
  - Secondary knows the hash state
  - Packets lost retransmitted



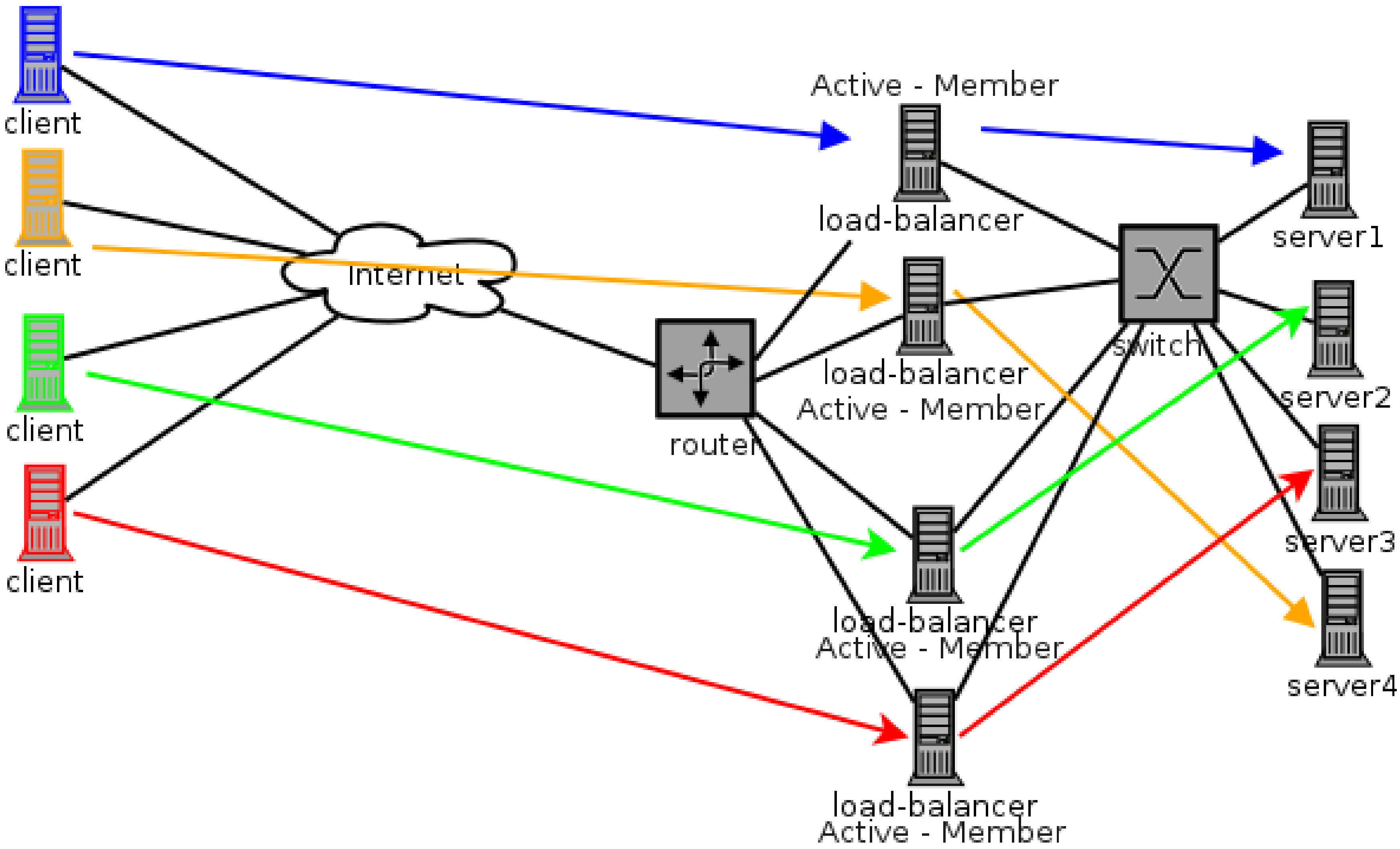
Active / Passive

- Active-passive failover requires a mechanism
- Could use:
  - VRRP (Virtual Router Redundancy Protocol)
  - CARP (Common Address Redundancy Protocol)
- If failover is not coordinated with load-balancer-health, a failed load-balancer may remain active (coordination problem).
- If state is not replicated between load balancers, failover will not account for existing connections (not a problem for short-lived connections with no affinity)

Active / Passive Cont

- Affinity can be preserved with a Cookie
- LVS (linux virtual server) can do state-replication (using a kernel module)
- State-replication doesn't help with scaling performance-wise (at all)

Active/Active

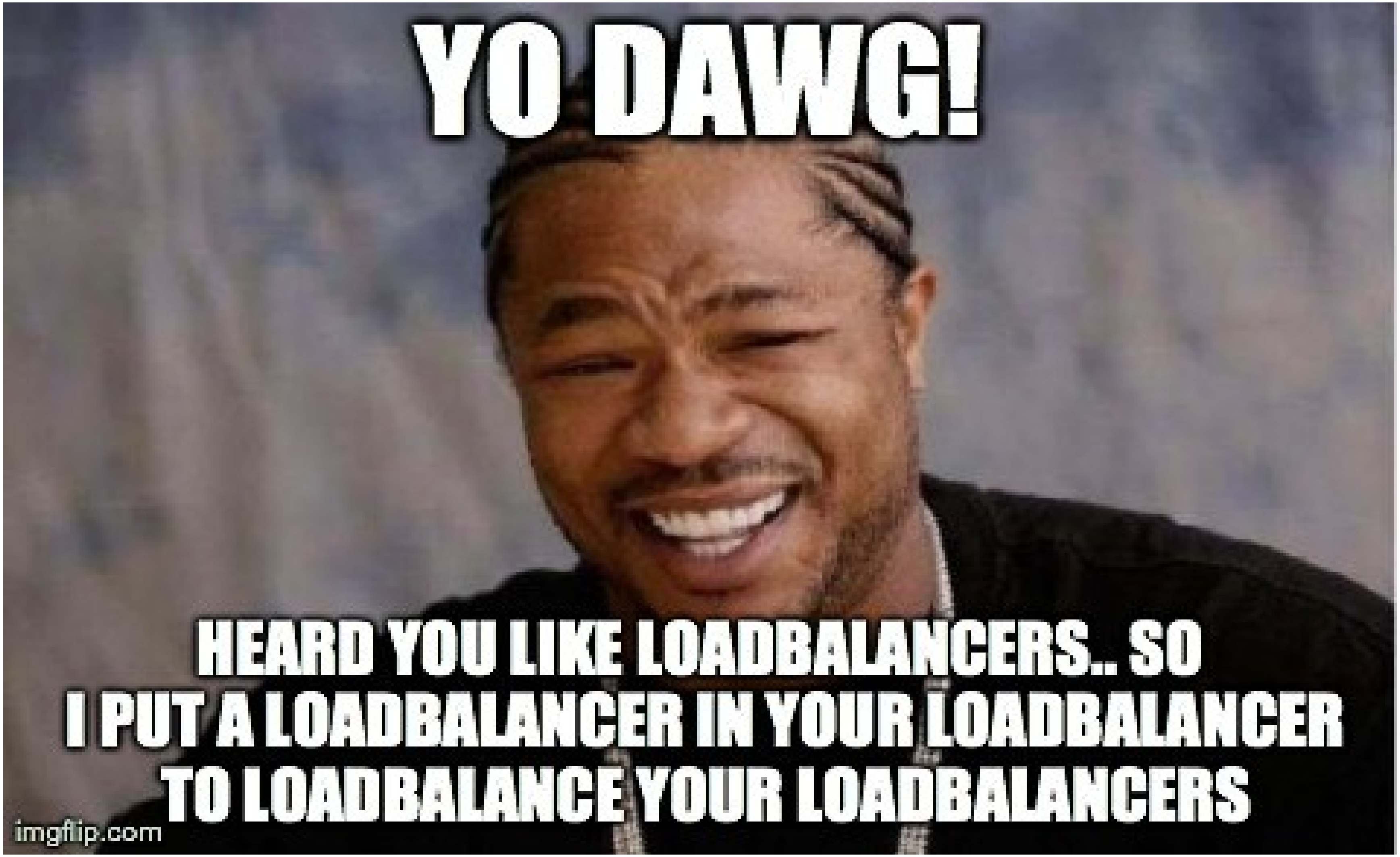


Active/Active – How?

- Need a mechanism to distribute requests to multiple front end load-balancers. In effect, a load balancer for your load balancers.
- HOW?
  - DNS e.g. each LB has a separate ip address associated with resources it's load-balancing
    - Return one or more resource records either randomly or on some externally instrumented basis.
    - Fail load balancers in or out using health check or manually
  - L2 or L3 stateless plus sticky mechanism.

Turtles all the way...

- When do we stop?


YO DAWG!
HEARD YOU LIKE LOADBALANCERS.. SO
I PUT A LOADBALANCER IN YOUR LOADBALANCER
TO LOADBALANCE YOUR LOADBALANCERS
imgflip.com

Active/Active – Stateful vs Not

- Stateful is typically done by clusters of commercial load-balancers. State replication can be expensive and imperfect.
    - At scale, can be extremely expensive
    - Memory on cluster members and bandwidth/cpu for replication is the limiting factor for state and connections per section.
- Stateless
    - In the DNS case resource records for a failed LB have to time out of caches before that LB stops being used.
    - In the L3-ECMP case a failure will cause some fraction of connections to rehash across other load-balancers anywhere from a quarter to half (they will then be rendered out of state and lost).

Our Exercise - HAProxy

- We're going to deploy HAProxy to load-balance connections to two http servers.
- HAProxy can do L4 (any TCP) or L7 (HTTP) load balancing
- We're going to do L7, this allows us to access http related features, including for example including a cookie.

HAProxy vs NGINX

  - L4 vs L7
  - HAProxy can load balance anything over TCP or do L7.
  - NGINX is L7 only (HTTP(s) and IMAP/POP3).
- SSL
  - HAProxy doesn't support (can't only treat as TCP)
  - NGINX does, so cookies for example can be parsed, can be used for SSL offload etc.
- Model
  - HAProxy is threaded, effectively allowing it to engage multiple cpus in the activity.
  - NGINX uses an event driven single threaded model.
  - Both have merit, HAProxy is probably more scalable.

Goals

1) Install and perform a basic configuration of HAProxy.
2) Configure two additional webserver instances on alternate ports.
3) Demonstrate load-balanced-http connections between them.
4) Log X-Forwarded-For.
5) Bonus: use a cookie to pin a requesting host to one server or another.
6) Bonus: Remove failing servers from LB pool.

Bootstrap..

- $ pkg install git
- $ git clone https://github.com/afnog/sse.git
- $ cd sse/loadbalancing/exercises/loadbalancer/
- $ Follow the trail by changing dirs and reading readmes
  - $ cd 01...
  - $ cat Readme.md
- Or browse github: https://github.com/afnog/sse/tree/loadbalancing/loa

Bibliography

- HAProxy - http://haproxy.1wt.eu/
- NGNIX - http://wiki.nginx.org/Main
- F5 LTM - http://www.f5.com/products/big-ip/local-traffic-manager.html
- A10 Networks - http://www.a10networks.com/
- Apache mod_proxy_balance - http://httpd.apache.org/docs/2.2/mod/mod_proxy_balancer.html
- Linux virtual server - http://www.linuxvirtualserver.org/index.html
- Wikipedia CARP - http://en.wikipedia.org/wiki/Common_Address_Redundancy_Protocol
- Wikipedia VRRP - http://en.wikipedia.org/wiki/Virtual_Router_Redundancy_Protocol